USE OF HONEYCOMB SPACER FABRIC AS GROUNDED VERTICAL AGRICULTURE PRODUCTION STRUCTURE

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ABSTRACT

The honeycomb fabric is designed to provide an alternative to soilless vertical farming practices. Also, the fabric can be improved as a fabric that provides increases the agricultural land, and reduces water consumption and use of pesticides. In the research, the experiments at the greenhouse environment by the prototype fabric are shared. Research findings show that it is necessary to make new prototypes using variables such as raw material, density, and color difference. As a result, a production project has been developed to observe the interaction of vertical cultivated plants with different qualities of fabrics in the greenhouse environment.

Key Words: Honeycomb Fabric, innovative textiles , vertical agriculture, vertical farming.

1. INTRODUCTION

However, the fabric has to be developed in accordance with the conditions and requirements of different usage areas. To confirm the thesis—that it is possible to use the fabric as construction in vertical agriculture—it is necessary to test the suitability of plant physiology for horizontal planting. To pre-test in a greenhouse environment, honeycomb fabric with a 10cm pore diameter produced with nylon 6.6 yarn was used as the material. In this pre-study conducted voluntarily, the data were collected using a monitoring-based method to collect information before the project. In the pre-study conducted with the Lactuca sativa plant known as Lollo Rosso, in three different soil qualities placed in the fabric, it was observed that there were no problems related to the growth of the plant seedlings planted horizontally [1]. It has been observed how much the fabric can respond to the performance values required by vertical agricultural production during the preliminary study period. As a result of the preliminary work, the properties of the fabric, which are required to make it suitable for grounded vertical agriculture were determined. In line with these identified properties, a project was prepared for the development of honeycomb fabric for use in vertical agriculture.

2. HONEYCOMB FABRIC AS AN INNOVATIVE FABRIC STRUCTURE

The honeycomb fabric produced as a result of the research to adapt the golden ratio rules to the textiles has a multi-layer structure that is connected between with special weaving technique. The honeycomb fabric, which can be produced without requiring any modification in the loom weaving machines, has a flat appearance while weaving. When the fabric is removed from the machine, the upper and lower surfaces are expanded in different directions, depending on the distance between the fabric layers. The expanding fabric has channels with hexagonal cross-sections, which continues between openings at both edges. What makes the fabric new and different is its multi-purpose channel structure and high strength.

The honeycomb fabric weaving by six individual weft yarns where the layers are weaving separately. There is three individual weft use where the layers join. The most important feature that makes the weaving technique different is that the warp grouped for six separate layers travels between the layers. The warp group forming the first fabric layer in order turn

weaves each fabric layer. This design not only increases the strength of the fabric but also homogenizes the rate of use of the warp and prevents the tension differences in the warp. In this way, the fabric which must be produced with six different warps can be produced by the single warp.

The honeycomb fabric has won the first prize of Technical Textile Projects Competition organized by the Association of Textile Raw Material Exporters at Turkey in 2012. The patent and the license rights of the weaving technique of the fabric and products which can be used in different areas produced by this technique are registered on behalf of the designer (Patent Nr. 2013/02671). Hexagonal honeycomb form provides maximum structural strength and maximum usage volume in the unit area [2]. When compared to other forms, it can be seen that it provides maximum storage area by being produced with the minimum amount of materials. Honeycomb fabric is not the first fabric in which hexagonal form is used. However, it is the first fabric in which the fabric layers are joined together by weaving without the need for stitching or bonding. The fabric can be used in vertical agriculture, storage, military textile products, insulation, filtering, packaging, liquid treatment, transportation, etc. By means of development and adaptation of the fabric into different areas, its areas of usage can be more than the ones mentioned above.

The prototype productions of the fabric are produced in four different connection sizes by using 1000 denier nylon 6,6 yarn from warp and weft at a width of 140 centimeters and 48-24yarn/cm density in the 16-frame dobby loom in the Oztek Tekstil Company. ISO 13934-1 Tensile strength and tear resistance test, ISO 13937-4 Tear properties test and ISO 12947-2 determination of the abrasion resistance tests of the fabric have been conducted in an independent organization [3]. The test result has shown that the fabric has very high strength values as below (Table 1).

Table 1. Tests values of honeycomb fabric (Oztek Textile, Textile Engineer Serdar Tunc)

Honeycomb	ISO 13904-1	ISO 13907-4	ISO 12947-2
Warp	14500N	950N	>100.000
Weft	9500N	840N	

The fabric has a wide application area. It’s a practical and functional design which can bring solutions to the problems of different sectors. One of the usage areas of honeycomb fabric is storage. Shelf systems used for storage purposes are not practical and healthy enough for a majority of the products because of the loss of the place due to empty spaces on the shelves, and problems with insect infestation, oxidation, corrosion and mildew can harm the products. Shelf materials occupy a large volume and also their mounting and storage costs are high. The work of archiving and placement of the product is not convenient [4]. Honeycomb fabric is easily assembled on metal construction as it is lightweight and takes up less space. A separate container is provided for each product. Products are not scratched, crushed or worn out. Thanks to allows air circulation between the pores of fabric, bacteria does not form.

Multi-layered structure and high strength values of the fabric shows that the product is a viable option to be used as the ballistic barrier. Usually, sandbags that are filled with local sand or soil are used to protect soldiers and structures. The transfer of sand-filled bags means labor and cost. The honeycomb fabric can be used as a ballistic barrier when it is filled with sand. It's practical to use and transport.

Purification of wastewater contaminants has become more of an issue in regard to the decrease in resources and to environmental pollution. As known, the use of fabric in the liquid treatment process increases the quality of the treatment [5]. The honeycomb fabric is recommended as a simple and inexpensive method that reduces the loss of decontamination materials and is suitable for use in different fields. Honeycomb fabric can also be used to contribute to thermal isolation, by separating air circulation levels.

3. HONEYCOMB FABRIC AS A CONSTRUCTION FOR VERTICAL AGRICULTURE

With the use of said fabric in vertical agriculture and horticulture; maximum volume is obtained in unit area, and besides its ease of use, it significantly reduces the costs of labor irrigation, transportation, cultivation area, greenhouse area, etc. In addition to these, it also minimizes the harmful factors such as soil loss and carbon release [6]. The reason for the reduction of costs in irrigation: During irrigation, water reaches the soil and the plant by passing through the pores of the honeycomb fabric. With the fabric, transmission of water through the pores from the uppermost layer down to the lowermost layer is provided in an efficient manner. In addition, since soil cannot pass through the pores together with the water, soil loss is prevented.

In improved applications of the honeycomb fabric, insecticides are transferred to the fabric via the microencapsulation method to remove agricultural pests from the field of the plantation [7]. This increases agricultural efficiency without soil and plants being contaminated with insecticides. In another improved application of the fabric, honeycomb fabric provides more minerals to the soil according to the needs of the plant to be grown with nanotechnology [8]. It is possible that this target can be realized by mixing these minerals with the soil in certain proportions via irrigation. By means of finishing operation and changing the fabric parameters, the fabric may be given non-flammable, antibacterial and antistatic features.

3.1 Preliminary Trial Study in Greenhouse Environment with Honeycomb Fabric

The honeycomb fabric having a 10cm hole diameter was cut in 200x50cm dimensions and placed in a metal construction with dimensions of 50x70x170 cm. 170 outdoor garden plants were planted in fabric holes for a technical textiles project contest demonstration. This application for the demonstration was placed outdoor for one month, during which time the fabric did not show any deformation due to weight and irrigation. This demonstration has shown that the fabric is suitable for vertical gardening applications.

The horticulture departments of various universities were contacted many times, but a return to a partnership could not be established for a project on the use of the fabric in vertical gardening and vertical agriculture. In 2017, Izmir Ege University Faculty of Agriculture Department of Horticulture, Department of Greenhouse Major Science academicians has shown an interest in the subject and supported a preliminary study to create a project. For this pre-study, 50x70cm fabric with a 10cm hole diameter placed in a metal construction with dimensions of 50x70x80 cm is placed in one of the greenhouses of Ege University.

The prior aim of the study was to observe the suitability of plants for growth and root release tendency and to discover whether the fabric provided the necessary conditions for the growth of the plant. Since it is a small, easy, fast-growing plant that responds quickly to external factors, Lactuca sativa plant, which is frequently used in similar studies was preferred for this study [9]. After the filling of three types of soil with different qualities to the fabric holes with the contributions of volunteer students, seedlings were planted in the pores into the honeycomb fabric hanged on metal construction on 14.04.2017. Planted plants were irrigated for fourteen days through on the fabric surface. At the end of fourteen days, the plants reached maturity to be harvested. During the study, it was observed that the plants provided adaptation to the planting direction.

Figure 1(left). planting seedlings in honeycomb fabric 14.04.2017(Source: Autor)
Figure 2(right). the plants that matured in the honeycomb fabric 28.04.2017 (Source: Autor)

During the study, it was observed that the plants provided adaptation to the planting direction. It was observed that the fabric density was suitable for irrigation and no soil loss occurred as a result of irrigation. It has been learned that 10cm diameter hexagonal holes are suitable for planting, but it is difficult to fill the holes with soil. It was observed that the soil was poured out of the two open sides while the soil was filled. Especially in the planting of broad-leaved plants, it has suggested that it would be more suitable to plant by leaving one hole empty between each plant. It was observed that the fabric was adversely affected by the sun and the white fabric was yellowed. At the end of fourteen days, it was reported that algae formed and emitted a bad odor in the parts of the fabric in contact with the soil. It has proposed to produce the fabric in dark color.

This preliminary work was not an experiment based on scientific data but provided important information for the use of honeycomb fabric in vertical agriculture. In line with the results obtained from the preliminary study, a project was prepared for the use of honeycomb fabric in vertical agricultural applications.

3.2 A Research Project Proposal for the Use of Honeycomb Fabric in Vertical Agriculture

To determine the usability of honeycomb fabric in vertical agriculture and to determine the conditions of use, it is necessary to carry out the experiments in which scientific data can be obtained. An interdisciplinary project has been developed due to the need for the expertise of

disciplines such as textile design, textile engineering, agro-engineering, and industrial products design. Due to the fact that it is a comprehensive project, this article mainly focuses on textile design and textile engineering side of the project. The aim, scope and stages of the project are summarized.

The project, based on the thesis that honeycomb fabric is usable in vertical agriculture, aims to test whether the fabric is a practical, healthy and economical product suitable for the production of grounded vertical agriculture in greenhouse conditions. With the project, which proposes a soil-based production system, which can be carried out with the traditional knowledge of the greenhouse growers, it is planned to develop an alternative to the existing landed vertical agricultural practices to increase agricultural areas.

The project consists of three stages. In the first stage, it is necessary to produce the fabrics to be used in the project according to the information obtained from the preliminary work. At this stage, it is planned to use black 1000 denier black polyester yarn colored from poy, which has better UV degradation resistance than nylon [10]. It is predicted that the selected material will prevent yellowing and algae formation in the fabric. For the experiments planned to be made with different plants, it is necessary to produce fabric with three different hole diameters of 10cm, 12cm and 14cm. It is planned to produce 140 cm width using a double warp beam in 16 frame rapier weaving looms. The purpose of the double warp beam is to divide the warp density into two parts to relieve the work of the machine and produce more metering at one time. To separate the produced fabrics into 45 cm wide sections, it is necessary to perform cutting operations on laser cutting machines for better cutting quality than on classic cutting systems [11]. In parallel with the fabric production, it is planned to develop a hanging system that will enable the watering, planting and harvesting stages of the fabrics in the greenhouse in the most effective way with the cooperation of industrial designers and agro-engineers. Again, with the same team, filling tools will be designed to facilitate the placement of the compacted soil in the fabric holes. Plants and sowing-harvest timelines to be used in the experiments will be created by the agro-engineers.

The second phase of the project is the implementation and experimental phase. At this stage the fabrics will be hung on the hanging system placed in the greenhouse environment. After the fabric holes are filled with soil, the field engineers will do the planting. At this stage, agricultural engineers will measure the growth times and productivity values of plants. Biological and chemical structures of the samples taken from plants will be compared with the other species produced by other agricultural methods. At the production stage, the textile design and textile engineering disciplines will evaluate the durability performance of the fabric and determine the aspects that need to be developed. Experts from the industrial product design discipline involved in the project will oversee the performance of the hanging system they have developed.

At the final stage of the project, it is planned that the stakeholders involved in the project will form reports in line with their own disciplines. Textile designers are expected to evaluate the performance of the fabric in line with the requirements in the field, to produce a report in which they use this information to improve the fabric structure and diversify the products. It is expected that textile engineers will present a report on the adaptation of the new products developed by textile designers to serial production. It is expected that a report by the industrial design designers about the aspects that should be developed to meet the expectations, and how they can provide cost and performance balance in case of mass

production. The agro-engineers are expected to produce reports that include comparative scientific data to prove whether the fabric is suitable for plant development, healthy for food production and an economic product for mass production. As a result of the project, these reports are planned to be converted into academic publications. The detailed file of the project, which is explained above in summary, is being prepared and the sponsoring organizations are investigated.

3. CONCLUSIONS

Although the study conducted prior to the project on the use of honeycomb fabric as a basic construction in grounded vertical agriculture did not provide scientific data, it provided information that would be useful for the actual research. Through the preliminary study that demonstrates the suitability of honeycomb fabric for vertical agriculture, the disciplinary areas that should be included in the project have been determined. This experience shows that the pre-work that can be done before the creation of similar projects will be helpful in determining the problems that may occur in the original project and determining the scope of the project by reducing the number of variables.

In the event that the results of the proposed project are positive, it will be possible to create with honeycomb fabric a low-cost alternative system suitable for the conditions of soil-based production, which greenhouse farmers are accustomed to. If the fabrics used in the project do not give the expected results, it will allow the creation of successive projects to make the fabric more efficient.

It is considered that the project is preparing an interdisciplinary field of study that will enable many academic publications from different disciplines. Increasing the usefulness of technical textiles in vertical agriculture and vertical horticulture areas can be realized by conducting similar studies and supporting research in this field.

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